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(54) IMPROVEMENTS IN AND RELATING TO FIBRE REINFORCED BUILDING PRODUCTS

(71) We, DANSK ETERNIT-FABRIK A/S, a Company organised under the laws of Denmark, of Postboks 763, 9100 Aalborg, Denmark, and ANTHONY JOHN METCALF ROBINSON, a British subject of 30 John Street, London, WC1N 2DD, do hereby declare the invention, for which we pray that a patent may be granted to us, and the method by which it is to be performed, to be particularly described in and by the following statement:

This invention relates to a method of manufacturing a building product by mixing a hydraulic binding agent, i.e. a binding agent which sets with water, as a matrix with a fibre reinforcement and to the product so manufactured. The invention also relates to a fibre-reinforced building product. Particularly, but not exclusively, the invention is concerned with the manufacture of fibre reinforced building sheets and the composition of sheets so manufactured.

Fibre reinforced building products of the construction described are well known. Such products are based on a matrix consisting mainly of a hydraulic binding agent such as Portland cement, alumina cement, fly ash cement, lime, gypsum, diatomaceous earth, puzzolan and mixtures thereof. Fibres used for the reinforcment may be organic or inorganic fibres or a mixture of fibres, and fibres which have been proposed include asbestos, glass fibres, steel fibres, mineral fibres, cellulose fibres and plastics fibres.

The resources of asbestos fibres suitable for the production of such fibre reinforced building products are limited and for many purposes it is desirable to avoid the use of asbestos as reinforcement fibres. Further it is a drawback when using glass fibres and steel fibres that such fibres are very expensive, and to achieve the same extent of reinforcement the expenditure will be 4-5 times as high as if asbestos had been used. Besides, glass fibres and steel fibres are inclined to decompose to some extent, the latter only insignificantly though, and only at the surface of the fibre reinforced material, whereas the former continuously undergo a certain decomposition as a consequence of the alkali-nature of the cement.

From British patent specification No. 1.130.612 it is known to use fibrous reinforcement components made from an elongated and subsequently fibrillated plastic film material preferably a polyolefin film. The abovementioned disadvantages in connection with asbestos fibres, glass fibres and steel fibres do not occur when the aforesaid material is used in a mortar consisting of e.g. Portland cement and gravel, but because of their extremely smooth surface only a poor bond to the matrix after setting of same is achieved. A side view of a bundle of fibres having smooth surfaces is shown in Figure 1. The fibre reinforcement known from said British patent specification consists of twisted plastic twine weighing 1-1,5 g/m, and having been cut to filaments of approximately 75 mm. The twine is made as a so-called split fibre material from a film-shaped plastic band, which upon extrusion and cooling has been stretched to approximately ten times its original length. The stretching causes the structure of the plastic material to become more orientated with resultant significantly increased tensile strength lengthwise, and significantly reduced tensile strength perpendicularly thereto.

Because of its poor tensile strength crosswise, the elongated material gets a natural tendency to split-up; this splitting-up may e.g. be brought about by twisting the stretched plastic film band around its longitudinal axis, and by further mechanical impact, e.g. as a consequence of blows or forces of friction from stone and gravel particles during admixing in a concrete mixer, in a method according to which they

are split-up in several thinner strings. By the known splitting-up the division into thinner strings will always take place along the native weakest lines or areas of the material parallel to the direction of elongation of the band. Thus the fibres formed get rectangular cross-sections, always completely smooth surfaces, and constant cross-section throughout their length, this being the reason why it has been impossible to achieve an anchorage more satisfactory than is the case with the usual round fibres. The smooth surface and the constant cross-section of the plastic fibres used up to now also account for the inadequate control of a homogeneous crack distribution in the hardened plastic fibre reinforced product. This disadvantage is further aggravated by the fact that the crosswise contraction properties of the plastic materials are extraordinarily high, viz. 0.4-0.5 as compared with approx 0.2 in case of glass and approx. 0.3 in case of steel. Thus by elongation, the smooth fibre will, as soon as strain is applied, get thinner, by which it loses intimate contact with the surrounding matrix along smaller or larger areas of its circumference, and along its entire longitudinal direction.

As a remedy it has been suggested only to let the splitting-up take place along a section of the full length of the twine, offset within the fibre bundle, so that when spreading the bundle, a material is achieved which may resemble netting having various widths of meshes. It is said that by this is achieved an anchorage which cannot be obtained with the usual round plastic fibres, but also the reinforcement of this kind is insufficient. The comparatively few crossing points, which by the way separately are rather weak as the splitting-up may just continue, are unable to a significant extent to surmount the influence of the very long areas with completely smooth cleavage faces, deriving from the splitting-up, to which a cement matrix cannot adhere, and consequently they do not yield the desired effect. As previously the known plastic fibre twine is shown in Figure 1 on the drawing.

The known splitting-up of fibres may take place by exposing the stretched plastic film to a certain physical treatment. However, they form coherent bundles of fibre filaments even after the vigorous handling they are exposed to as a result of the mixing with gravel and stone in the concrete mixer. The cross-section of the individual fibres will still be so large that a certain resilient movement will occur when the fibres have been bent, which is the case after compression of the fibre containing concrete mass, and this in itself causes a poor anchorage of the fibres too.

According to one aspect of the present invention, a method of manufacturing a building product comprises mixing a slurry of a hydraulic binding agent as a matrix and a plurality of fibrous reinforcing elements at least a portion of which are flexible, organic oriented polyolefin fibres, each having a weight from 2 to 35 denier and having cross sections which vary along its length and polyolefin fibrils extending from surface portions thereof and permitting said slurry to set after forming or moulding.

According to a second aspect of the present invention, a method of producing a building product comprises the steps of:

a) taking polyolefin film material capable of being molecularly oriented by stretching so as to define a direction of orientation,

b) stretching said orientable film material at least fifteen times its length to a thickness of from 10 to 60 microns,

c) cutting said film material by means of a rotating needle or cutter roller along lines at least partially transverse to the lines of natural weakness caused by the molecular orientation of said material thereby to produce filaments having cross sections which vary along their lengths and frayed surface portions with fibrils of said material extending therefrom,

d) cutting said filaments into lengths of produce fibrous reinforcing elements each having a weight of from 2 to 35 denier and being capable of being anchored in a matrix admixture and of maintaining surface contact with the admixture to provide fibre reinforcement of a product produced from said admixture,

e) mixing said fibrous reinforcing elements with a hydraulic binding agent,

f) mixing said hydraulic binding agent and fibrous reinforcing elements in the form of a wet slurry, and

g) permitting said admixture to set after forming or moulding.

Thus in the preparation of the reinforcement in the form of the stretched film material, stretched in one or more stages, the fibrillating is carried out by chopping, for example by means of rollers with cutters or needles which cut or split the stretched film partly across the direction of the strong cores of the material.

The fibres are thereby fibrillated in such manner that they are frayed at the edges thereby improving the binding of the fibres in the matrix. However, it is important that the reinforcement is obtained by splitting it up completely into single filaments dispersed in the slurry which is obtained by the method.

Preferably the fibres are polypropylene fibres which are able to withstand direct or indirect influence from variations in light and temperature which for building parts

may vary from about minus 20° C up to about 120° C. By polypropylene fibres is in this context especially included pure polypropylene fibres made on the basis of a film material without polyethylene usually admixed to facilitate the drawing and stretching of the film material.

According to a preferred feature of the invention the fibre material is dispersed in a part of the binding agent, which thereafter is mixed with the remainder of the matrix material.

Because of the frayed edges and uneven character of the fibres and the many attached and very thin fibrils, the fibres in question are very difficult to disentangle and distribute evenly in the matrix material. In order to achieve the necessary dispersion of the fibres, the admixing may in a first step preferably take place in part of the matrix material, for example in a neat Portland cement matrix.

Thus it is an advantage that the dispersion of the fibres is made in a fat or highly viscous fluid.

From the concrete manufacturing industries it is a well known fact that a high strength is obtained with a low water-cement ratio whereas asbestos cement requires a high water-cement ratio to obtain acceptable strengths of the articles.

Surprisingly enough it has been realized that the strength of articles made in this manner with a lower water-cement ratio and said fibres are increased considerably compared to asbestos-cement articles manufactured with the required high water-cement ratio.

To improve the adherence of the flexible organic fibres the surface of them may be treated with an inorganic filler material of a size range in which 85 per cent by weight is smaller than 1 micron or part of the binding agent by mixing the fibres therewith before mixing with the matrix material. The fine grained filler material also serves to plasticise the mixture to obtain an even dispersion of the fibres.

Further improvements in the admixing may be obtained in a method according to the invention in wich the admixing of the fibres to the matrix mass is carried out with the addition of a dispersing agent.

The dispersing agent may serve to improve the distribution of the fibres and part of the fibres may serve as dispersing agent as for instance cellulose fibres but also chemical compounds such as methylcellulose, hydroxypropyl-methylcellulose, polysiloxanes, silicone oils, mineral oils with silicone derivatives may be used also to improve the affinity of the fibres and avoid lumping of the fibres and thereby improving the random orientation of the fibres.

The admixing of the fibres in an amount up to about 20 per cent by volume to the matrix material may be performed in mixers preferably without stirring devices, for instance in mixers of the vibrating, shaking or tumbling type.

The method according to the invention is especially applicable in a process in which the product is manufactured in the form of sheets on fibre-sheet-forming machinery with suction equipment for dewatering the green sheets in the forming process.

The mixture of fibres cooperate to obtain a good performance of the slurry in the machinery of the aforesaid kind.

The other fibres consist of cellulosic fibres and perhaps inorganic mineral fibres, e.g. mineral wool fibres or the like and, added properly, they can, because of their very large specific surface, ensure an even distribution of the cement particles in the complicated sieve system that the plastics fibres form, and when the water surplus is subsequently sucked away during the setting and forming of the material, the carrying fibres form a filter which prevents the cement particles being drawn away from the surface of the plastic fibres.

An improved product is obtained if the sheets are subjected to a compression for a period of time after forming.

The present invention further comprises, according to a third aspect, a fibre reinforced building product manufactured from a matrix of a hydraulic binding agent and a plurality of fibrous reinforcing elements at least a portion of which includes individual filaments of oriented polyolefin fibres cut from polyolefin filaments cut from polyolefin film material which has been stretched at least about 15 times to a thickness of about from 10 to 60 microns, said fibres having cross sections which vary along their length and polyolefin fibrils extending from surface portions thereof, each polyolefin fibre further having a weight of from 2 to 35 denier, a tensile strength of at least about 4000 kp/square cm, a modulus of elasticity of at least 7×10^4 kp/square cm and a maximum elongation of up to 8 per cent of the length, the length of said fibres being between 5 and 25 mm.

It has been found that fibres produced in this manner, because of their firm anchorage in the cement, are capable of absorbing the full tensile load when the cement fails, and that at the same time they, because of shearing stresses along the fibre surface, can lead to the production of a distribution of microcracks so extraordinarily fine that the product functions as a homogeneous one-component material to the very point of breaking having an extension which may be between 10 and 100 times that which is the case with the unreinforced matrix material; such extension has been unattainable when

using the plastic fibre reinforced building materials proposed up to now.

When the plastic film material is split-up by means of a cutter or needle roller when the plastic film material is stretched close to the limit of rupture, the plastic film is split-up into little strips and units of somewhat differing widths, normally between 3 and 7 times the gauge of the plastic film. Figure 2 of the drawing shows a cross-section through such a fibre bundle. When splitting-up, it is important that the cutting is made at places which do not coincide with the native weakest areas in the material. When cutting, the plastic film is cut through somewhat at random, and often in directions deviating from the direction of elongation, which presumably happens because the roller path when hit by one or other of the needles of cutters, respectively, is pushed into certain sidewise movements in its own plane. Consequently, cutting over of the strong cores of the material often occurs - this causing a certain fraying of the areas of cut - and further, the cross-section of the individual fibres differ in the longitudinal direction. Both these facts appear from Figures 3 and 4 of the drawing. The fine fibrils and the fraying can be seen anywhere in the areas of cut, and it is also evident that the two areas of cut are not quite parallel as is the case with the naturally split-up stretch film, but that they project and recess at random in the case of each individual fibre. These instances of unevenness cause the particularly fine anchorage and mechanical interlocking of the fibres in the building material according to the invention.

According to a fourth aspect, the present invention consists in a fibre reinforced building product manufactured from a matrix slurry of a hydraulic binding agent such as Portland cement and a plurality of fibrous reinforcing elements, at least a portion of which are single filaments of oriented polyolefin fibres each having a tensile strength of about from 4000 to 6000 kp/square cm, a modulus of elasticity of from 7 to 10 × 10^4 kp/square cm, and a maximum elongation of up to 8 per cent, said polyolefin fibres having a weight of 2 to 35 denier and being between 5 to 25 mm in length and having cross sections which vary along their length and frayed edges with fibrils extending therefrom so as to permit anchoring of said fibres in the matrix slurry.

Splitting-up of a plastic film material by means of cutter or needle rollers is known per se, but it is novel to cut it over in order to divide the material, thus achieving single filaments and to use these non-smooth fibres with uneven cross-sections and the abovementioned stipulated properties, as plastic fibre reinforcement in the form of single filaments in a building material; the reason for this is maybe to be found in the fact that the plastic fibres here mentioned as a consequence of their peculiar nature are much more difficult to distribute in a cement material than is the case with the smooth plastic fibre materials used up to now.

It has been tried, without success, to disperse polyolefin fibres in water according to the normal procedure which is used when, for example, dispersing asbestos fibres with a view to producing asbestos cement, or as is the normal procedure in case of cellulosic fibres. The more agitation the more the fibres entangle. However, when using a mixture of fibres including carrying fibres, e.g. cellulose fibres, it has turned out that a normal dispersion may be obtained even without the addition of dispersing additives. Surprisingly enough, it has turned out that when using a fat or highly viscous fluid a perfect dispersion may be carried out quite easily.

Fibre reinforced materials according to the invention have been thoroughly tested in the laboratories and in actual use and compared with usual asbestos reinforced cement products prepared in the same manner; with the same compression they show stress-strain characteristics on the same level, whereas the elongation at rupture and the impact resistance have been found to be considerably higher, viz. 3 to 5 times those of the asbestos reinforced cement products. Figure 5 illustrates stress-strain curves from bending tests with various materials.

Curve 1 shows an unreinforced cement matrix. Curve 2 shows a cement matrix reinforced with smooth polypropylene-twine and curve 3 illustrates a product reinforced according to the invention. In the drawing:

Ordinate δ, edge bending stress,

abscissa ε, edge strains in the tensile and the compressive zone (both shown as positive) repsectively ε_t and ε_c.

According to a modification of the invention the polypropylene fibres are composed of two sizes of fibres, the ratio of the lengths being about 1:3. By using various sizes of the fibres an improved dispersion of the fibres in an interlaced fashion is obtained, for example with a mixture comprising 6 mm and 18 mm fibres.

Other types of fibres, especially cellulose fibres and/or mineral fibres may be added to improve the filtration characteristics of the slurry, i.e. as mentioned above to serve as a filter forming base in the prepared slurry enabling sheets to be prepared on conventional sheet manufacturing machinery in which a layer of slurry is deposited on a screen or felt with simultaneous dewatering by suction. Meanwhile, these relatively fine fibres serve as a strong bond of the matrix

mass.

According to a preferred feature of the invention the matrix material includes a fine grained inorganic filler material of a size range in which 85 per cent by weight is smaller than 1 micron.

The fine grained material has as mentioned above an important function during preparation of the slurry for the manufacturing of the product by plasticising the mass and in some instances also by serving as a temperature regulating additive to keep the reaction temperature within certain limits. However, in the product prepared the fine grained filler material, for example puzzolan or fine grained slag, serves to react with and control the free lime always present in the product and further improves the strength of the product.

The invention will be further illustrated by the following Example.

A heat stabilized film of pure polypropylene having a gauge of 35 microns was stretched by a factor of 20 and fibrillated by mechanically splitting the stretched film by means of a rotating cutter roller. The resulting flexible organic fibres were of irregular cross-section along the length of each fibre and varied in cross-section from fibre to fibre and were somewhat frayed. The fibres had widths of between 3 and 7 times the gauge of the film and had a denier of about 20. Some of them were chopped into lengths of approximately 6 mm and others were chopped into lengths of approximately 18 mm. The resulting chopped fibres were mixed together and then mixed with a quantity of Portland cement. The treated fibres were then mixed into a stiff mixture of Portland cement, water and methylcellulose as a dispersion agent in a vibratory mixing machine to disperse the fibres. Further water, further Portland cement, cellulose fibres and puzzolan having a size range such that 85% was smaller than 1 micron were then added and thoroughly mixed to produce a slurry. The slurry was used in a conventional asbestos-cement sheet making machine to produce a fibre-reinforced cement sheet, the machine providing suction for dewatering and means for pressing the sheet for a period of time after forming.

WHAT WE CLAIM IS:-

1. A method of manufacturing a building product comprising mixing a slurry of a hydraulic binding agent as a matrix and a plurality of fibrous reinforcing elements at least a portion of which are flexible, organic oriented polyolefin fibres, each having a weight from 2 to 35 denier and having cross sections which vary along its length and polyolefin fibrils extending from surface portions thereof and permitting said slurry to set after forming or moulding.

2. A method of manufacturing a building product as claimed in Claim 1 in which the polyolefin fibres are polypropylene fibres.

3. A method of manufacturing a building product as claimed in Claim 1 or Claim 2 in which the said fibres are dispersed in a part of the binding agent, which thereafter is mixed with the remainder of the matrix material.

4. A method of manufacturing a building product as claimed in any of the preceding claims in which the surface of the flexible organic fibres is treated with an inorganic filler material of a size range in which 85 per cent by weight is smaller than 1 micron or part of the binding agent by mixing the fibres therewith before mixing with the matrix material.

5. A method of manufacturing a building product as claimed in any of the preceding claims in which the admixing of the fibres to the matrix mass is carried out with the addition of a dispersing agent.

6. A method of manufacturing a building product as claimed in any of the preceding claims in which the product is manufactured in the form of sheets on fibre-sheet-forming machinery having suction equipment for dewatering the green sheets in the forming process.

7. A method of manufacturing a building product as claimed in Claim 6 in which the sheets are subjected to a compression for a period of time after forming.

8. A method of manufacturing a building product as claimed in any of the preceding claims in which the film material is heat stabilized and the binding agent is Portland cement.

9. A method of manufacturing a building product as claimed in any of the preceding claims in which the polyolefin fibres have a tensile strength of at least 4000 kp/square cm.

10. A method of manufacturing a building product as claimed in any of the preceding claims in which the polyolefin fibres have a modulus of elasticity of at least 7×10^4 kp/square cm.

11. A method of manufacturing a building product as claimed in any of the preceding claims in which the polyolefin fibres have an elongation up to 8 per cent.

12. A method of manufacturing a building product as claimed in any of the preceding claims in which the polyolefin fibres have a length between 5 and 25 mm.

13. A method of producing a building product comprising the steps of:

a) taking polyolefin film material capable of being molecularly oriented by stretching so as to define a direction of orientation,

b) stretching said orientable film

material at least fifteen times its length to a thickness of from 10 to 60 microns,

c) cutting said film material by means of a rotating needle or cutter roller along lines at least partially transverse to the lines of natural weakness caused by the molecular orientation of said material thereby to produce filmaments having cross sections which vary along their lengths and frayed surface portions with fibrils of said material extending therefrom,

d) cutting said filaments into lengths to produce fibrous reinforcing elements each having a weight from 2 to 35 denier and being capable of being anchored in a matrix admixture and of maintaining surface contact with the admixture to provide fibre reinforcement of a product produced from said admixture,

e) mixing said fibrous reinforcing elements with a hydraulic binding agent,

f) mixing said hydraulic binding agent and fibrous reinforcing elements in the form of a wet slurry, and

g) permitting said admixture to set after forming or moulding.

14. A method as claimed in Claim 13 which includes the step of applying heat to said stretched film material to stabilize said material in said stretched condition prior to the step of cutting said material by means of a rotating needle or cutter roller.

15. A method of manufacturing a fibre reinforced cement sheet substantially as described herein in the foregoing Example.

16. A fibre reinforced building product made by a method as claimed in any of the preceding claims.

17. A fibre reinforced building product manufactured from a matrix of a hydraulic binding agent and a plurality of fibrous reinforcing elements at least a portion of which includes individual filaments of oriented polyolefin fibres cut from polyolefin filaments cut from polyolefin film material which has been stretched at least about 15 times to a thickness of about from 10 to 60 microns, said fibres having cross sections which vary along their length and polyolefin fibrils extending from surface portions thereof, each polyolefin fibre further having a weight of from 2 to 35 denier, a tensile strength of at least about 4000 kp/square cm, a modulus of elasticity of at least 7×10^4 kp/square cm and a maximum elongation of up to 8 per cent of the length, the length of said fibres being between 5 to 25 mm.

18. A building product as claimed in Claim 17 in which said polyolefin fibres are polypropylene fibres.

19. A building product as claimed in Claim 18 in which the polypropylene fibres are composed of two sizes of fibres the ratio of the lengths being about 1:3.

20. A building product as claimed in Claim 17 or Claim 18 or Claim 19 in which part of the fibres is cellulosic fibres.

21. A building product as claimed in Claim 20 in which part of the fibres is inorganic mineral fibres.

22. A building product as claimed in any of Claims 17 to 21 in which the matrix material includes an inorganic filler material of a size range in which 85 per cent by weight is smaller than 1 micron.

23. A fibre reinforced building product manufactured from a matrix slurry of a hydraulic binding agent such as Portland cement and a plurality of fibrous reinforcing elements at least a portion of which are single filaments of oriented polyolefin fibre each having a tensile strength of about from 4000 to 6000 kp/square cm, a modulus of elasticity of from 7 to 10×10^4 kp/square cm, and a maximum elongation of up to 8 per cent, said polyolefin fibres having a weight of 2 to 35 denier and being between 5 and 25 mm in length and having cross sections which vary along their length and frayed edges with fibrils extending therefrom so as to permit anchoring of said fibres in the matrix slurry.

24. A fibre reinforced building product as claimed in Claim 23 in which said single filament polyolefin fibres are polypropylene fibres.

25. A fibre reinforced building product as claimed in claim 24 in which said single filament fibres are polypropylene fibres of from 2 to 35 denier cut from polypropylene filaments cut from polypropylene film which has been stretched at least 15 times its original length to a final thickness of from 10 to 60 microns.

KILBURN & STRODE,
Chartered Patent Agents,
Agents for the Applicants.

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1605004 COMPLETE SPECIFICATION

3 SHEETS *This drawing is a reproduction of the Original on a reduced scale*

Sheet 1

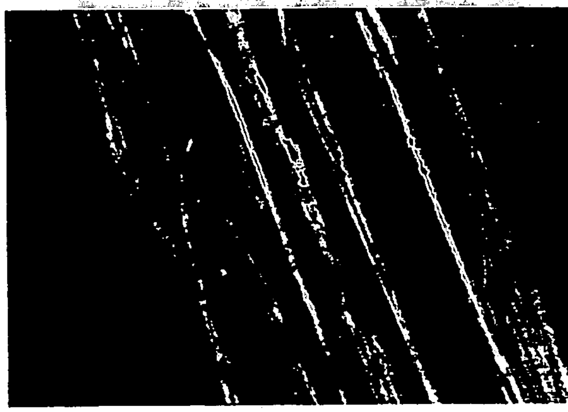

Fig 1 100×

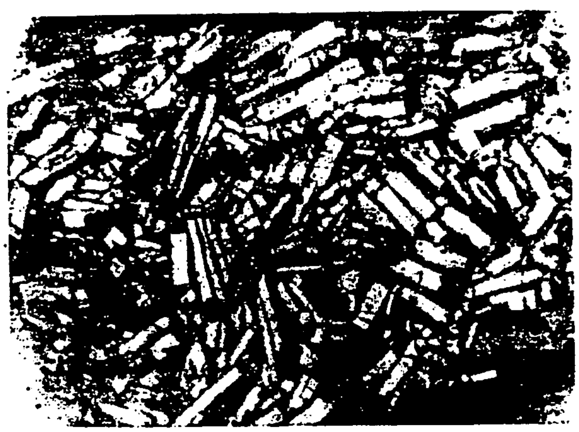

Fig 2 130×

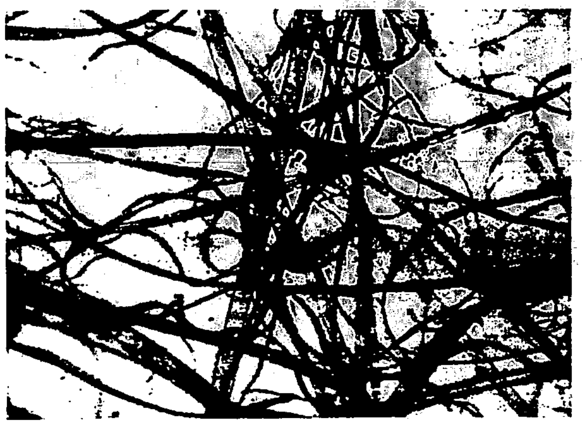

Fig 3 100 x

Fig 4 100x

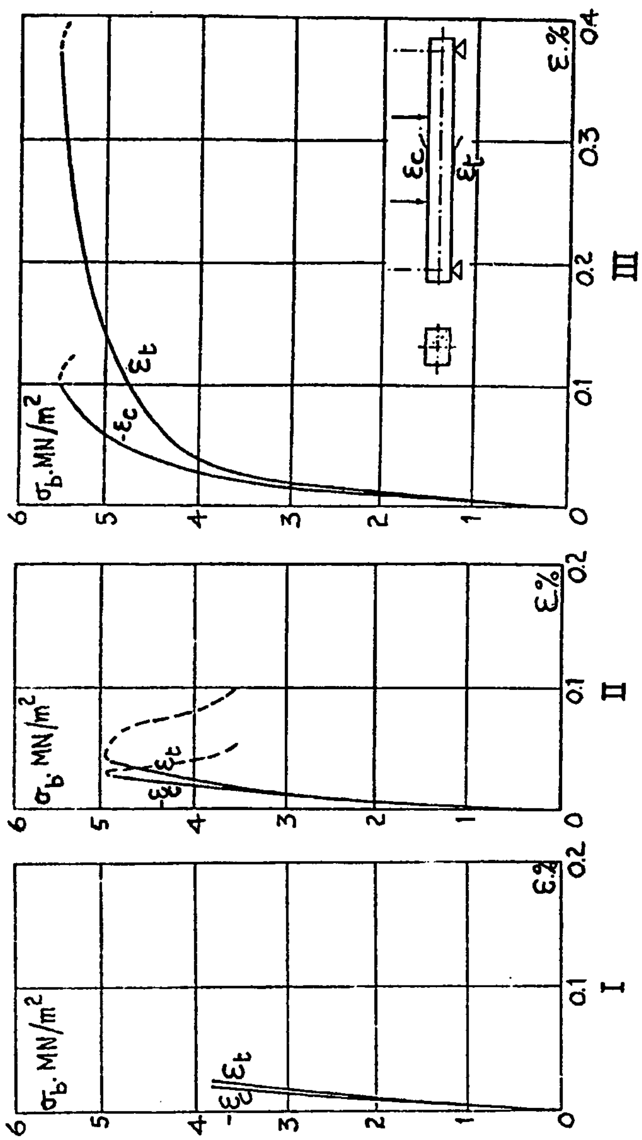

Fig 5